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The use of boreal relict shrub habitats of willow-leaf meadow sweet (*Spiraea salicifolia*) and shrubby cinquefoil (*Potentilla fruticosa*) in Western Rhodope Mts. by mammal species

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Abstract

Plant communities of two peat-shrub species – *Spiraea salicifolia* and *Potentilla fruticosa* were studied in the Rhodope Mts., with emphasis on their use as a resource for the mammals associated with them. These shrubs are boreal relicts among the dominant coniferous forests. The field surveys were conducted in the spring-autumn period of 2021–2022. In both study areas, the species composition of the mammals was studied by camera traps for medium and large mammals, and by Sherman live traps for small mammals. The species registered were roe deer (*Capreolus capreolus*), red fox (*Vulpes vulpes*), wild boar (*Sus scrofa*), pine marten (*Martes martes*), European hare (*Lepus europaeus*), red squirrel (*Sciurus vulgaris*), bank vole (*Myodes glareolus*) and yellow-necked mouse (*Apodemus flavicollis*). Having in mind that small mammals are vital prey base for avian and mammalian predators, it is not surprising that *M. glareolus* and *A. flavicollis* individuals were captured in the habitats that they probably use as shelters. The pine marten inhabits the forests by which the community of *P. fruticosa* is surrounded, but probably feeds on the rodents in the shrub. In this way, it probably provides it with an alternative to the forest food base and hunting ground. From the presented results, it seems that the *L. europaeus* uses *P. fruticosa* shrubs as food. Therefore, the plant communities of the two relict peat-shrub species studied probably provide shelter and food for the mammals. Their importance is established for at least one species of mammal with conservation significance at national and European level – *M. martes*. Therefore, it is necessary to continue and expand the future monitoring on mammal diversity of these relict communities.

Keywords

camera traps, endangered species, live traps, mammals, relict shrub habitats

Introduction

Relict species have an important position in Earth's biodiversity. Various studies are known on the relict nature of many boreal plant species such as *Parnassia palustris*, *Salix lapponum*, *Potentilla fruticosa*, etc. (Čarni and Matevski 2015; Horsak et al. 2015; Serafin et al. 2018). Due to their sedentary lifestyle and role in habitat foundation, relict plants have employed various strategies in adapting to their environment even under dramatic climatic changes such as glaciations. Their populations preserve ecological and evolutionary histories that can last thousands of years (Woolbright et al. 2014) but are also threatened by climatic changes, which narrow their range of distribution (Hampe and Jump 2011). Against this background, many studies have indicated climatic influences on mammal population dynamics, usually acting together with a complex set of biotic factors (Humphries 2009). With the changes in global temperatures and consequent changes to habitats, a clearer understanding of the relationship of mammals with the environment has become imperative. Hence, it is of particular interest what mammals inhabit the relict communities and how they use them. Determining habitat associations of mammal species and the environmental characteristics important for site occupancy is central to understanding species biology and community organization. The aim of the present study is to explore the use of two relict shrub habitats of willow-leaf meadow sweet (*Spiraea salicifolia*) and of shrubby cinquefoil (*Potentilla fruticosa*) in the region of Western Rhodope Mts as a resource for the mammals associated with them.

The two shrub habitats are assessed as critically endangered (Gussev and Vulchev 2015; Tzonev and Gussev 2015) at a national level. A particular feature of these shrub communities is the combination of standing water or high soil and air humidity with low temperatures characteristic of boreal and tundra biomes more broadly distributed in the northern latitudes. This, together with the richness of northern and boreal floristic elements and their complexity in terms of origin and evolution, significantly affects their habitat value as a refuge of relict plant, invertebrate and vertebrate species. Due to their glacial (boreal) relict origin, these habitats are threatened by climatic changes, which narrow their range of distribution relative to all boreal and glacial relicts (Hampe and Jump 2011). Many relict boreal plants, or even community types and animal communities related to them, growing along the southern edge of their range and/or at their altitudinal and climatic limits, are expected to be heralds of adverse climatic changes (Freeman et al. 2018; Beniston 2000; Fescenco et al. 2020). Global warming in mountain plant communities is accompanied not only by extreme heat waves, drought, and severe forest fires (Allen 1994), but also by invasion pressure from lower-elevation plant communities and species (Lenoir et al. 2008). Surveys of relict boreal plants or their communities growing near the extremes of their ecological tolerance could help to estimate the pressure of climate change on the ecosystems and promote better understanding and conservation of potential refuge areas for vulnerable to global warming species. In European mountains various studies have investigated the impact of recent climatic changes on mountain flora and vegetation (Dirnboock et al. 2011; Pauli et al. 2012; Cannone and Pignatti 2014; Steinbauer et al. 2018) as some expected

and unexpected results were found, such as: elevation upshifting or downshifting for different plant groups; increase of local species richness and decrease of rare or endemic boreal plants. The significance of boreal mires and shrubs related to them as endangered habitats for boreal relict plant and animal invertebrate species has already been studied in Bulgaria (Hajek et al. 2009, 2010; Langourov et al. 2018). However, there is still little information about their habitat use by mammals (Benedek et al. 2021). Establishing what species of mammals inhabit these communities will help to initiate effective monitoring programs in the context of climate change.

Materials and methods

Characteristics of *Spiraea salicifolia* and *Potentilla fruticosa* habitats

The investigated habitats are located and occupy areas in West Rhodope Mts., Southwest Bulgaria (Fig. 1). The communities in the studied sites are small and intra-zonal phenomenon, being surrounded on all sides by the boreal coniferous forests that dominate in Rhodope Mts. These forests are formed mainly by spruce (*Picea abies*), fir (*Abies alba*) and scots pine (*Pinus sylvestris*) (Bondev 1991). Both habitats form close and dense communities characterized by high soil moisture and represent parts of a huge natural complex of boreal peatlands and bogs in the zone.

The main characteristics of the two communities were based on their floristic composition and ecological features and were determined as follows:

P. fruticosa thickets are distributed in Beglika locality (41°50.11"N, 24°08.67"E), near Batak town at 1510–1530 m a.s.l., covering an area of about 1.2 ha (Tzonev and Gussev 2015) (Fig. 1). The soils are *Humic Cambosols* (Ninov 2002). The communities occupy mountain slopes with low inclination, between 2 and 5 degrees. They are dense and closed with high coverage of the dominant species. The total vegetation cover is 90–100% (Fig. 2). The cool and humid climate and substrate predetermine the development of mesophilic and cold-resistant plants. Almost 60 species and subspecies of vascular plants (excluding bryophytes) are part of the composition of the *P. fruticosa* community with most species in the families *Rosaceae*, *Poacea*, *Asteracea*, *Apiaceae* and *Fabaceae*, represented by 4–7 species each.

The communities of *S. salicifolia* occupy flattened river terraces along Dospatska River, (41°45.45"N, 23°59.00"E), near Dospat town, at 1210–1250 m a.s.l., covering an area of about 4.8 ha (Gussev and Vulchev 2015) (Fig. 1). The soils are *Fluvisols* with a thick humus layer and acidic reaction (Ninov 2002). *Spiraea salicifolia* forms dense, almost monodominant thickets along Dospatska River. The cover of the dominant species *S. salicifolia* is higher than 80% (Fig. 3) with herbaceous plants of low abundance. About 40 species and subspecies of vascular plants (excluding bryophytes) are part of the composition of the *S. salicifolia* community. The plant families with highest number of species are *Rosaceae*, *Poaceae*, *Fabaceae* which are also the biggest families in the general Bulgarian flora (Assyov and Petrova 2012).

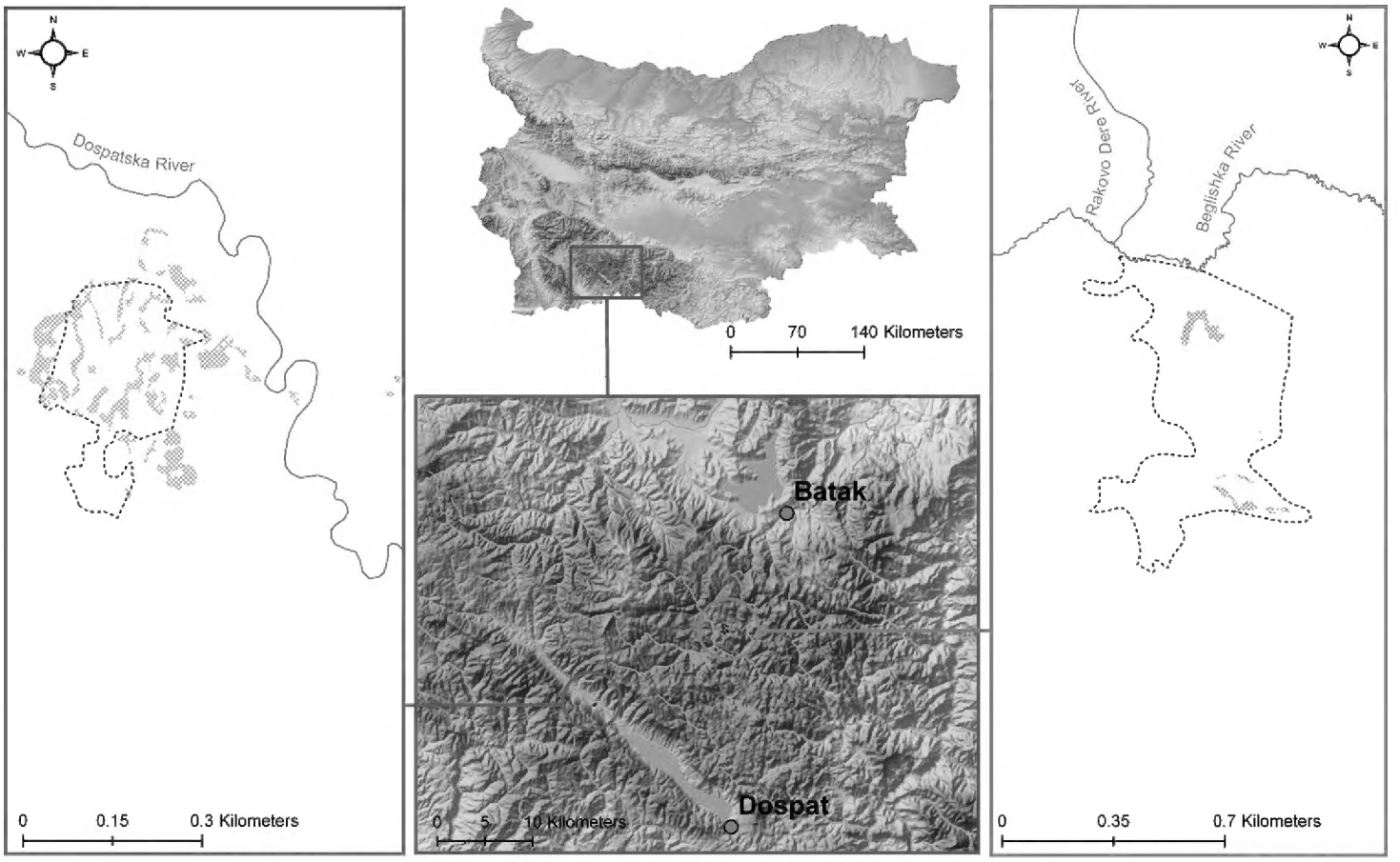

Figure 1. Map of distribution of the investigated habitats in West Rhodope Mts.

Figure 2. Rhodope thickets of *Potentilla fruticosa* – individual plant (**A**) and habitat (**B**).

The climate in these regions is typical of the boreal coniferous forest belt where both habitats are distributed. It is humid with mean annual temperature of 7.3 °C (Batak) and 8.1 °C (Dospat), and annual precipitation of 912 mm and 966 mm respectively (Fig. 4).

S. salicifolia and *P. fruticosa* are listed in Annex 3 of the Bulgarian Biodiversity Act. The territories occupied by their communities have been declared protected sites, "Chibutsite" and "Hrastoviden ochibolets" respectively, and are included in the Natura 2000 network (Fig. 1).

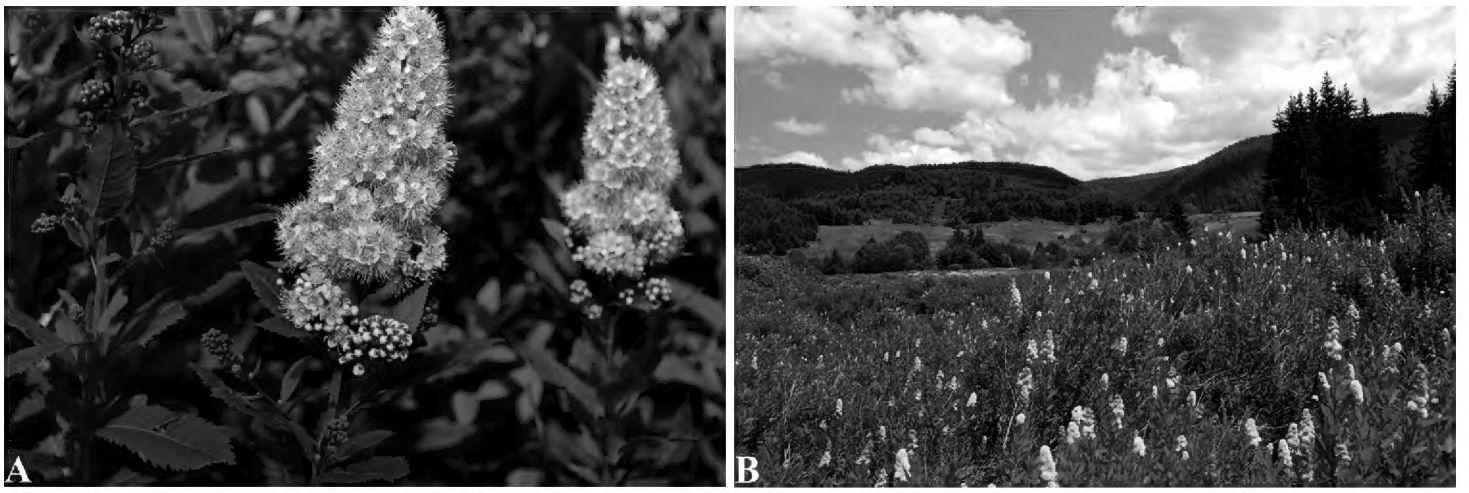

Figure 3. Rhodope thickets of *Spiraea salicifolia* – individual plants (**A**) and habitat (**B**).

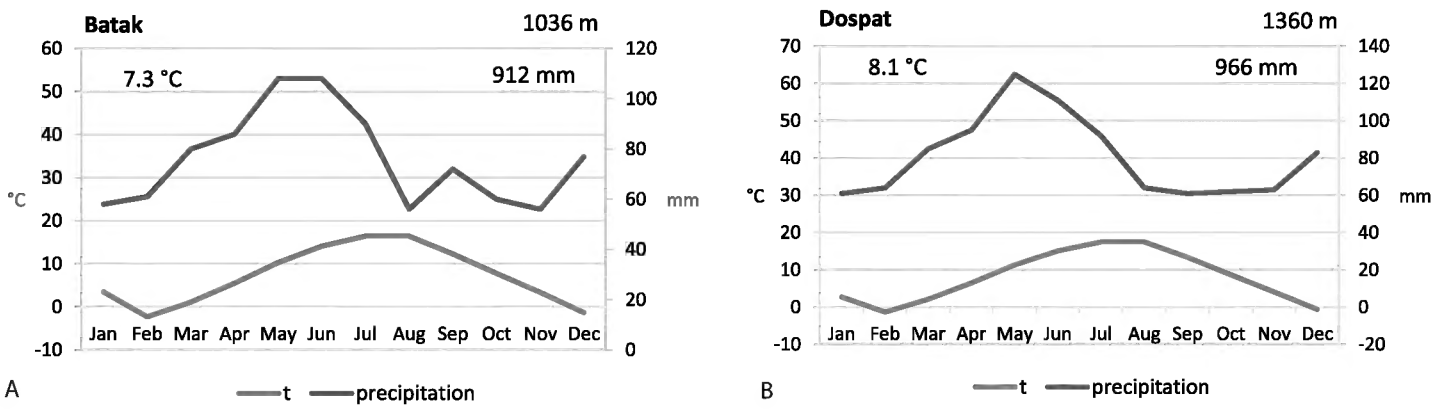

Figure 4. Climate diagrams for the towns **A** Batak (*P. fruticosa* habitat) and **B** Dospat (*S. salicifolia* habitat). The model is based on weather data collected for the period 1991–2021 and has a resolution of 0.1–0.25 grade (data source Climate-Data.org).

Mammals' data collection

The field surveys were conducted in the spring-autumn period of 2021 and 2022. In both habitats over areas of about 0.5 to 1 ha, the species composition was studied with camera traps (Moultrie M-40) for medium and large mammals, and by Sherman live traps (H. B. Sherman Traps, Inc., Tallahassee, Florida) for small mammals (Fig. 5).

A total of four camera traps, two at the edge of each community, were installed on trees at the height of about 50 cm. The effort was the same at the two habitats – 167 trap-nights average per habitat (142 for 2021 and 192 for 2022).

A total of forty Sherman live traps baited with oat nuts were set per habitat. The live traps were placed in lines at a distance of about 10 m from each other. To avoid animal disturbance the trapping was carried out for one night in each shrub habitat. All animals were released immediately after species determination at the place of capture. Relative abundance of small mammals was estimated on the base of the number of individuals captured per trap-night. Additionally, the presence of mammals was also registered by direct observation and traces of their activity.

Figure 5. Methods of mammal registration (**A**) camera trap (**B**) Sherman life trap.

Mammal identification

Species identification of mammals was made on the basis of external morphological features, body size, and ecology according to Popov and Sedefchev (2003). In Bulgaria, the wood mouse (*Apodemus sylvaticus*) and yellow-necked mouse (*Apodemus flavicollis*) do not differ in external morphological features. Using cranial measurements in a study on small mammal assemblages from North to South along the Bulgarian Black Sea coast, Popov (2000) established that *A. flavicollis* was better represented in the southern area where the forests were the prevailing vegetational type. In Central Western Bulgaria the majority of adult wood mice also belong to *A. flavicollis* (Minkova and Popov 2002) as well as in the Southwest part of the country (Popov 2015). This gives us reason to consider that, in all probability, the captured *Apodemus* individuals are *A. flavicollis*.

Ethical notes

The investigation conformed to the international requirements for ethical attitude towards the animals. All animals captured were released at the place of capture.

Results

In the *S. salicifolia* community, camera traps recorded the roe deer (*Capreolus capreolus*) and red fox (*Vulpes vulpes*), both nocturnally and diurnally (Table 1, Fig. 6).

Among the rodents, the red squirrel *Sciurus vulgaris* and *A. flavicollis* were photographed. Around the community, tracks of *C. capreolus*, *V. vulpes*, hedgehog (*Erinaceus concolor*), wild cat (*Felis silvestris*) and badger (*Meles meles*) were recorded as well. From the small mammals in the live traps the bank vole *M. glareolus* and the yellow-necked mouse *A. flavicollis* were captured (Fig. 7). Over the two years, the bank vole had a relative abundance 0.18–0.20 individuals per trap-night. The yellow-necked mouse was captured only in 2022 with a relative abundance of 0.20 individuals per trap-night.

In the community of *P. fruticosa* from the large and medium-sized mammals with the camera traps the roe deer *C. capreolus*, the wild boar *Sus scrofa*, *V. vulpes*, and the European hare (*Lepus europaeus*), as well as domestic horses (*Equus caballus*) were recorded. Two different individuals of pine marten (*Martes martes*) were recorded in April and May of 2021 and 2022 with the camera traps as well. The martens were registrated both during the night and the day (Fig. 8). From the small mammals, again the bank vole *M. glareolus* and the yellow-necked mouse *A. flavicollis* were captured. The bank vole was captured in both study years, while *A. flavicollis* was captured only in 2021. The relative abundance of the bank vole was 0.25 individuals per trap-night, and of the yellow-necked mouse 0.075 individuals per trap-night, respectively.

Table 1. Camera trap recordings of mammals in *S. salicifolia* and *P. fruticosa* habitats. Note: with * is indicated the presence of both day and night registrations.

	***S. salicifolia* habitat**		***P. fruticosa* habitat**	
Years	**2021**	**2022**	**2021**	**2022**
Recorded species	**Number of registrations**			
Capreolus capreolus	4	7*	3*	11*
Sus scrofa	–	–	–	2*
Vulpes vulpes	2	6*	1	3*
Martes martes	–	–	3*	10*
Lepus europaeus	1	–	4	12*
Sciurus vulgaris	–	2*	–	–
Apodemus flavicollis	–	8	–	–
Equus callabus	–	–	–	4

Discussion

The rodent species *A. flavicollis* and *M. glareolus* represented the small mammal community in our study. Their relative abundance is similar to those established by other authors in mountain regions (Benedek et al. 2021). According to Benedek et al. (2021) in most forests of Central and Eastern Europe *M. glareolus* and *A. flavicollis* are the dominant rodent species, with one or the other being more numerous depending on habitat conditions and geographic position. Our data are not sufficient to establish

Figure 6. Camera trap registration of *V. vulpes* in *S. salicifolia* habitat.

whether there is microhabitat segregation of the two rodent species in the studied habitats but, in other studies in mountanous areas, *A. flavicollis* seems to be more associated with the forest edge than *M. glareolus*, while the second species prefers areas within the forest with high tree and shrub cover (Hille and Mortelliti 2010). In our study *M. glareolus* was more numerous and captured in both habitats as well. Popov (2007) also found that in Bulgaria the *M. glareolus* is one of the rodent species with the highest abundance in mountainous regions. Based on its highest abundance in mountainous regions in Bulgaria we find that *M. glareolus* could be an indicator of climate change here. *Myodes glareolus* has been identified also as a key species in genetic studies for understanding the response of European fauna to climate change following the Last Glacial Maximum, being an example of a woodland mammal surviving in cryptic glacial refugia in Europe north of Mediterranean areas (Filipi et al. 2015).

Small mammals are also vital prey base for avian and mammalian predators. Therefore, it is not surprising that many small vertebrates prefer to forage under plant cover where it is more difficult for predators to detect them, avoiding areas with sparse cover or greater distances between shelters (Loggins et al. 2019). It is considered that the shrub cover is likely to have a strong influence on the species and communities of small mammals that rely on it for safety (Stephens and Anderson 2014). In this sense, the communities studied are very valuable for the small mammals found here, due to their location between open space and forest. Both habitats probably also serve as a shelter for roe deer, red fox and hare. These species were recorded both during the day and at night. From a camera trap video it seems that the hare is pulling and chewing a twig of the *P. fruticosa*. For herbivores, shrubs can be important food sources, but

Figure 7. Bank vole *M. glareolus* captured in *S. salicifolia* habitat.

are relatively sustainable to the grazing due to their deep root system, multiple stems, and height (Wikeem and Wikeem 2005). Besides, it is established that species such as birch-leaved spirea (*Spiraea lucida*; syn. *S. betulifolia*) are negligible in the diet of wild herbivores (Quinton 1984). However, the horses present in the area could be a threat to the shrubs due to trampling. Therefore, measures should be taken to monitor and control the number of domestic animals around the communities.

Figure 8. Camera trap registration of *M. martes* (**A**) and *L. europaeus* (**B**) in the *P. fruticosa* habitat.

In the community of *P. fruticosa* two pine marten were recorded. *Martes martes* is considered a habitat specialist mainly associated with forests (Clevenger 1994; Caryl et al. 2012; Lombardini et al. 2015). We assume that the pine marten inhabits the spruce forests surrounding the *P. fruticosa* community, but probably feeds on the rodents in the shrub community. In this way, it provides pine martens with an alternative to the forest food base and hunting ground. The *M. martes* is included in the Red Data Book of Bulgaria vol. II in the category of "Endangered" species (Spassov and Spiridonov 2015) and in the Biological Diversity Law – Appendix II and III. It is also included in the IUCN Red List, "Least Concern" category. The pine marten is a species that is

monitored within the National Biodiversity Monitoring System. The studies carried out in the two shrub communities provided data on its distribution at the national level and could be useful in clarifying its habitat specialization. However, more studies are needed to better understand the use of these boreal relict shrub habitats by mammals in the region. Like other authors such as Humphries (2009) we also think that it is necessary to continue and expand the examples of long-term monitoring of mammal diversity with more taxa and regions before it is too late.

Conclusion

The studied relict peat-shrub plant communities dominated by *S. salicifolia* and *P. fruticos*a in the Rhodope Mts. probably provide shelter and food for the mammals. Their importance is established for at least one species of mammal with conservation significance at national and European level – *M. martes*. The limited distribution of these communities makes it necessary to initiate a long-term program to monitor the impact of climate change on them and on their connection with the associated mammals.

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